Determination of Component in Binary Alloy by Backscattering of Beta Particles

Determination of Component in Binary Alloy by Backscattering of Beta Particles*

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Synopsis

The saturation backscattering of β particles changes by the atomic number of a target material and the maximum range of backscattered β particles from the same source also changes by the target material. These properties were applied to the quantitative analyses of the component elements in binary alloys. After investigating the backscattering of the particles emitted from Sr–90 (Y–90) and P–32 by various target elements with or without aluminium absorbers, the optimum conditions for the determination of copper in aluminium and tungsten in tungsten-iron alloy were found. Copper could be determined by counting the backscattering of β emission from Sr–90 (Y–90) through 345 mg/cm^2 absorber and tungsten could be determined with 490 mg/cm^2 absorber.

I. Introduction

β particle emitted from radioactive materials has a property of being reflected by target materials, generally in the original direction. This phenomenon is called the backscattering of β particles, which increases with the increase in the thickness of the target or with the increase in the atomic number of target material. This property of β particle has generally been applied in the estimation of the thickness of the material.

In the β source with maximum energy over 0.6 MeV, the saturation backscattered value of a material with the thickness over one-fourth of the maximum range of β particle used does not vary with the change in the thickness of target but depends on the atomic number of the target material. This property has been applied by T. Asahina, Hamada and Yamasaki[1] in the estimation of lead in ancient glass. Müller[2] has studied the relation between the compound material and the amount of backscattered β particles. It is also a well-known fact that the total counts of backscattered β particles are the sum of intrinsic counts of material components. The application of this fact in chemical analysis has been reported

* The 1070th report of the Research Institute for Iron, Steel and Other Metals. This report was originally published in Japanese in the Journal of Japan Chemical Society, **82** (1960), 333.

(1) T. Asahina, T. Hamada and H. Yamasaki, The First Congress for Use of Isotope in Japan, p. 636.

(2) R.H. Müller, Anal. Chem., **29** (1957), 969.

by Alinmarin[3], but precise data are unknown.

So, in the present reserach, the relation between the amount or the energy of backscattered β particles and the metallic element was examined, and the result was applied in the quantitative analyses of the components of binary base alloys.

II. Experiments and results

1. Apparatus and beta source

β source was prepared by using Sr–90 (Y–90) and P–32, which are emitting only β particles. The maximum energies of the emission from Sr–90 (Y–90) and P–32 are 0.53, 2.68 and 0.72 MeV respectively. The schematic diagram of source holder is shown in Fig. 1. The β source consists of a solder alloy cylinder, 5 mm in diameter and 5 mm in depth, and is supported by soldering with an

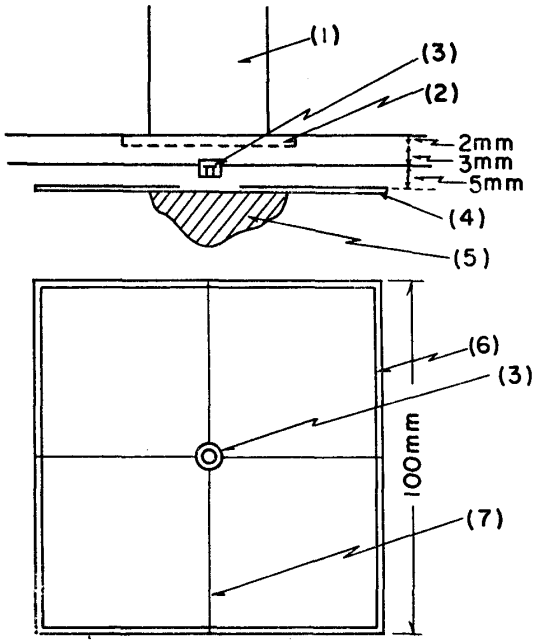

Fig. 1. Apparatus for backscattering measurements
(1) G.M. counter (2) Al-absorber (3) Betas source (4) polyethylene sheet (5) sample (6) Al-rim (7) thin wire

extremely thin iron wire laid on the center of a square aluminium rim. The length of each line of aluminium rim is 10 cm. At the center of the source holder, the collimating cylindrical hole, 1 mm in diameter, is drilled and β emitting radioisotope is mounted on it by injecting the solution of Sr–90 (Y–90) or P–32 and drying it. The surface of the hole is covered with thin films of collodion. The aluminium rim supporting β emitter is fixed on a polyethylene sheet, 1 mm in thickness and at the center of the sheet a hole, 1×1.5 cm^2 is cut, from which β particles

(3) P.L. Alinmarin, The 1st Geneva Congress for Peaceful Use of Atomic Energy, Chemical Section.

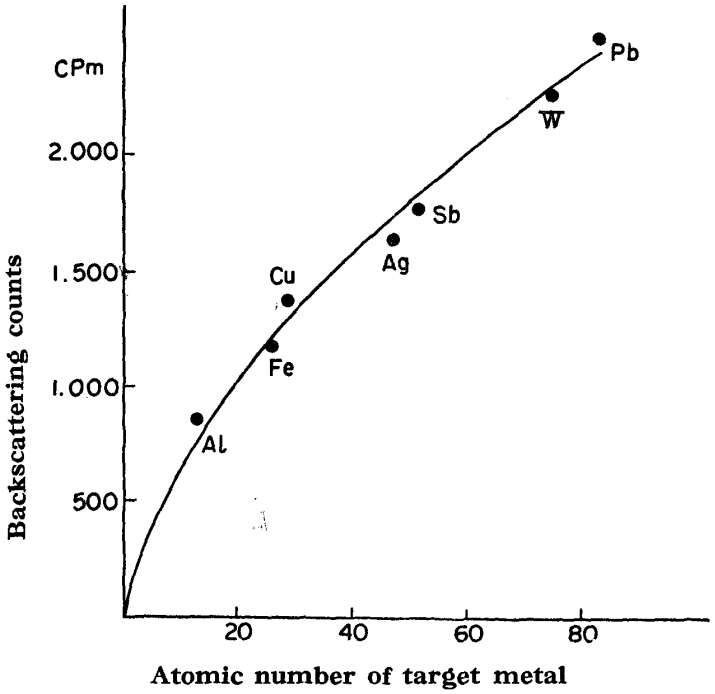

Fig. 2. Backscattering counts of betas particles for various metal targets measured by the proposed method (I)

Source : Sr-90 (Y-90)
target metals: block or plate of pure metals
counting times : 10 minutes

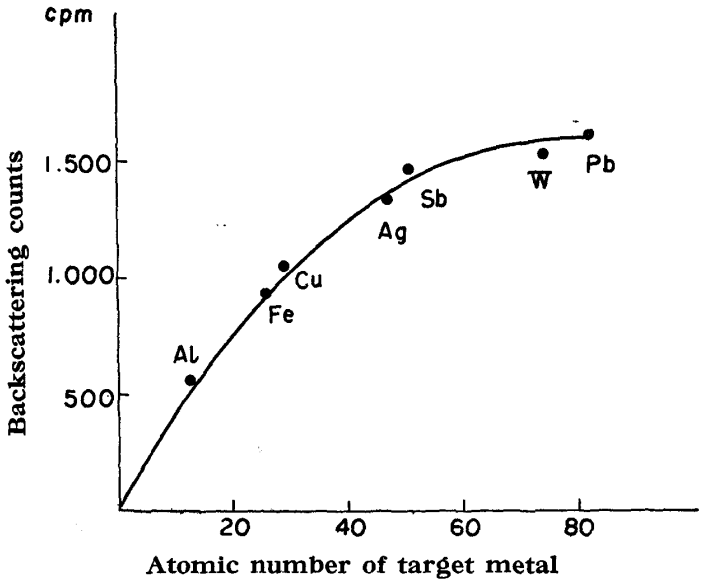

Fig. 3. Backscattering counts of betas particles for various metal targets measured by the proposed method (II)

Source: P-32
target metals: block or plate of pure metals
counting times: 10 minutes

irradiate directly the sample target and is backscattered.

The sample was stuck to the plate (sheet) firmly. This apparatus was placed in the sample holder attached to the counting stand for G.M. counter. The instrument used for β counting was the decimal scaler and G.M. counter made by Kôbe Kôgyô Co. The geometry and positioning for activity measurement is shown in Fig. 1 (b). The target metal is kept at 10 mm from the β source and the part facing to the source is polished plainly and smoothly. All samples were made so thick as to exceed one-fourth of the maximum range of β particles coming out of Y–90.

2. Saturated backscattering of various metals

Saturated backscattering of various kinds of pure metal was measured by the proposed apparatus. The results are shown in Figs. 2 and 3. In Fig. 2 Sr–90 (Y–90) and P–32 was used as β source. Saturation backscattering of these pure metals increased clearly with the increase of the atomic number of metal element. Hence, the backscattering measurement by this method would give the characteristic value of each metal element.

In order to test the precision of the backscattering, the ten-minute measurement was repeated five times in each element using Sr–90 (Y–90) as a β source,

Table 1. The absorption of backscattered betas by aluminium absorber (I)

Target elements	Counts per cent of betas through the absorber of		
	40 mg/cm	345 mg/cm	490 mg/cm
Al	51.9	0.5	—
Fe	67.0	8.8	—
Cu	69.1	9.7	—
Ag	70.7	14.5	1.3
W	74.8	16.0	6.4
Pb	74.6	17.8	9.7
Source	95.9	24.8	14.4

and the standard deviation was calculated. When the counting was made without sample metal, the counts were 70 ± 6 cpm for the source Sr–90 (Y–90) and 56 ± 5 cpm for the source P–32, These counts might be called the background through this experiment, considering that it was the sum of the direct beam from β source and the backscattering from walls of sample holder. The repeated measurements (counting) showed that the standard deviation of the backscattering of all metals investigated was all within the range of statistical error of each counting.

3. Energy absorption of backscattered β particles by aluminium absorber (Energy distribution of backscattered β particles)

Next an experiment was carried out to estimate the energy distribution of β particles backscattered by various metals. An aluminium absorber was placed just in front of the mica window and the count of backscattered β particles was taken. The results are shown in Tables 2 and 3, which show that the ranges of β particles backscattered by lighter metals – lower atomic number elements – are

Table 2. The absorption of backscattered betas by aluminium absorber (II)

Target elements	Counts per cent of betas through the absorber of		
	40 mg/cm	120 mg/cm	245 mg/cm
Al	43.7	—	—
Fe	50.0	16.1	—
Cu	50.1	20.3	—
Ag	56.8	26.1	3.8
W	58.5	27.8	5.7
Pb	62.0	30.0	7.0
Source	79.1	51.8	19.0

Source: P-32

smaller than those by heavier metals – higher atomic number elements. Of these metal targets, aluminium, the youngest atomic number metal, gave the highest percentage of the absorption of backscattered β particles by 345 mg/cm^2 absorbers. On the contrary, 10 per cent of the backscattered beta by lead had the maximum range nearly the same as that of the original beta emitted by Sr–90 (Y–90) or by P–32 and was able to come through 490 mg/cm^2 absorber. Applying these results, it would be possible to measure the backscattering from one element of a binary alloy metal by cutting the backscattered beta from the other element by an absorber. When Sr–90 (Y–90) was used as the source, for example, 2.18 MeV and 0.55 MeV beta backscattered from aluminium target would be cut off by 345 mg/cm^2 absorber, while those from copper were cut off by 490 mg/cm^2. Therefore, when β backscattering was measured by using 345 mg/cm^2 absorber, the counting value proportional to the concentration of copper could be obtained in the presence of aluminium.

4. Calibration curves for the elements in binary alloy

In Fig. 4 the relation between the backscattering of beta and weight per cent of copper in aluminium-copper alloy is shown, in which Sr–90 (Y–90) radioisotope as the β source and the absorber with 345 mg/cm^2 in range were used. The β backscattering is proportional to the copper concentration, which shows the applicability of this method in the determination of copper content in a binary

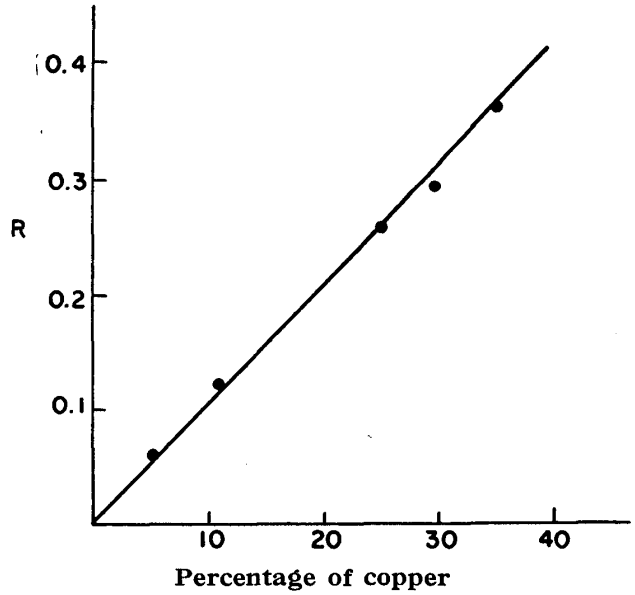

Fig. 4. Calibration curve for copper in Al-Cu
R: backscattering counts of sample/backscattering counts of pure copper
Al absorber: 345 mg/cm

alloy.

The same examination was made on iron-tungsten alloys. In this case β (emitted by Sr–90 (Y–90)) backscattering by iron would be cut off with the absorber of 490 mg/cm^2, while 6.4 per cent of backscattered beta from tungsten could still be transmitted through the absorber of 490 mg/cm^2. Then, by using 490 mg/cm^2 absorber, it was possible to obtain the calibration curve for the amount of tungsten in iron-tungsten binary alloy.

5. Determination of copper in aluminium-copper alloy and tungsten in iron-tungsten alloy

Applying the results described above, the determination of copper in aluminium-copper alloy and of tungsten in iron-tungsten alloy was carried out.

Part of the definite area of the sample surface was made flat and polished and the sample was stuck to a polyethylene plate by having the polished surface faced to β source. The backscattering was counted by using 345 mg/cm^2 absorber for copper and 490 mg/cm^2 absorber for tungsten. After the counting was finished, the sample was exchanged for the pure metal element to be estimated and the count of β backscattering was taken under the same condition as in the case of the sample. The ratio of count of the sample to that of pure metal $B_{SS}/B_{SM}=(R)$ was calculated, and from the previously obtained calibration curve for copper or for tungsten the content of copper or of tungsten in the sample was determined. The calibration curves were obtained as follows:– the backscattering counting ratio of aluminium-copper alloy (or tungsten-iron alloy) to pure copper (or pure tungsten)

metal was estimated by using the alloy with known amount of elements to be tested and by counting the backscattered beta through 345 mg/cm^2 absorber (or 490 mg/cm^2 absorber for tungsten). Then the curve was obtained from each count-ratio to the corresponding copper (or tungsten) content.

This method does not suffer from any source of accidental errors caused by changes in β source or in sample, and by the decay of the intensity of β emission. In Table 3 the results of the determination of copper in aluminium alloys and tungsten in iron-tungsten alloys are shown.

Table 3. The results of the determination of copper in Al-Cu alloy and tungsten in Fe-W alloy

Sample	Chemical method %		Betas backscattering method %	
Al-Cu Alloy	Cu	35.4	Cu	37.1
		25.8		26.5
Fe-W Alloy	W	77.8	W	76.2 75.8 77.1 73.2 75.2
		82.8		80.9
		77.6		78.2

Summary

The non-destructive quantitative analysis was investigated by using radioactive isotope elements from which only β particles are radiated. This enables the estimation of one component in a binary alloy to be simple and rapid. In tungsten determination, the deviation from the value obtained by chemical analysis was appreciable. This, however, could be minimized by measuring β counting for a comparative long time or with stronger β source. As β source, it seems to be optimum to use those radioactive isotopes of comparatively 'long half-life' emitting beta particles with maximum energy higher than 0.6 MeV.